

CDIO-BASED MASTER PROGRAMME IN PRODUCT DEVELOPMENT

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Abstract

In the autumn 2007, Chalmers University of Technology, Göteborg, Sweden, will launch 44 new Master's programmes, as a step in the Bologna process. The Master's programme in Product Development, one of these programmes, aims to provide an environment and course syllabus that gives students the knowledge, skills and attitudes to act efficiently within global product developing organizations. This includes specific technical knowledge related to product development, managerial skills to plan and control the process, and practical attainments in using advanced methods and tools for collaborative product development. The diversity of the intake, with students with an undergraduate background in mechanical, electrical, industrial management or industrial design engineering, is used as an asset, enabling student project to be truly multidisciplinary, addressing engineering as well as business development aspects.

This paper, will summarize the experiences of designing this programme using the CDIO standards and syllabus (www.cdio.org). In addition, the paper will discuss challenges when designing a curriculum in a programme description and making sure that overall learning objectives for the programme are met through individual courses and assessment methods.

Keywords: Author instructions, Deadlines, CDIO

Introduction

In the autumn 2007, Chalmers University of Technology, Göteborg, Sweden, will launch 44 Master's programmes, as a step in the Bologna process. The Bologna Process is an inter-governmental initiative which aims to create a European Higher Education Area (EHEA) by 2010 and to promote the European system of higher education worldwide [1]. It now has 45 signatory countries and it is conducted outside the formal decision-making framework of the European Union. Decision-making within the process rests on the consent of all the participating countries. It was launched in 1999 when Ministers from 29 European countries, met in Bologna and signed a declaration establishing what was necessary to create an EHEA by the end of the decade. The broad objectives of the Bologna Process became: to remove the obstacles to student mobility across Europe; to enhance the attractiveness of European higher education worldwide; to establish a common structure of higher education systems across Europe, and; for this common structure to be based on two main cycles, undergraduate and graduate.

Following the Bologna declaration, the new Degree Ordinance for all education programs from the Swedish Government [2] gives Swedish Universities the right to issue a masters degree starting from the 1st of July, 2007, equivalent to two years of study. The outcomes in the Degree Ordinance contain Dublin Descriptors [3] for the respective levels, complemented with a number

of learning outcomes relevant for professional engineering practice. However, these added outcomes reflect engineering as a whole, and are not specialized onto the sub-disciplines of engineering, such as chemical or mechanical engineering. Thus, they remain a baseline from which a program must derive its particular goals.

It is in line with this process, Chalmers University of Technology, Göteborg, Sweden, will launch 44 Master's programmes in the autumn 2007. The Master's programme in Product Development is associated to ("owned by") the 5-year Civilingenjör degree programme in Mechanical Engineering. In addition, it is also accredited ("selectable") to the Civilingenjör degree programmes Automation and Mechatronics, Industrial Design Engineering, and Industrial Economics and Management. To facilitate the design of these programmes, Chalmers developed guidelines for the design of programme descriptions [4], briefly described by Malmqvist et al. [5], based on the CDIO syllabus and principles [6].

Integrated Programme Descriptions

An integrated program description (IPD) [4, 5] describes the goals, content and structure of an educational program, as well as how these are connected. The intent is to provide the program chair and other key stakeholders involved in the program design process with a set of tools that can facilitate their design process. It also deliberately promotes a design process which emphasizes high-level considerations such as setting goals and developing the program idea. This facilitates the alignment of the goals and content of the program with actual stakeholder needs, and may point out necessary major changes which can be very difficult to motivate and implement when applying the more common practice of program (re)design to modifying an existing program plan. An integrated program description contains six basic components [4, 5]:

1. The *program purpose*, a high-level statement of why the program exists, which defines the overall purpose of the program, including its context and the future professional tasks and roles of its graduates.
2. The *program goals* define the knowledge, skills and attributes that the graduates are expected to have developed upon graduation. The program goals can be described as a concretization of the program purpose into a set of assessable learning outcomes.
3. The *program idea* describes how the program is designed in order to meet its goals. It states the main principles and considerations that underlie the program design.
4. *The program plan* is the formal specification of what courses are included in the curriculum, their credits and placement in the curriculum.
5. The *program design matrix* connects the goals of the program with its courses so that it is clear in which course each learning outcome is addressed. The program design matrix also shows the planned learning sequences (or development routes) for learning outcomes which are developed through integrated learning experiences throughout the curriculum, typically generic competences such as communication skills.
6. Finally, *course plans* define the purpose, goals and content of each of the courses in the program, and include a statement that explains the role of the course in the program, and links it to the program goals.

Figure 1 shows the relationships between the components. This sequence should not be enforced too strictly. It is important that the program design process allows for iterations, and

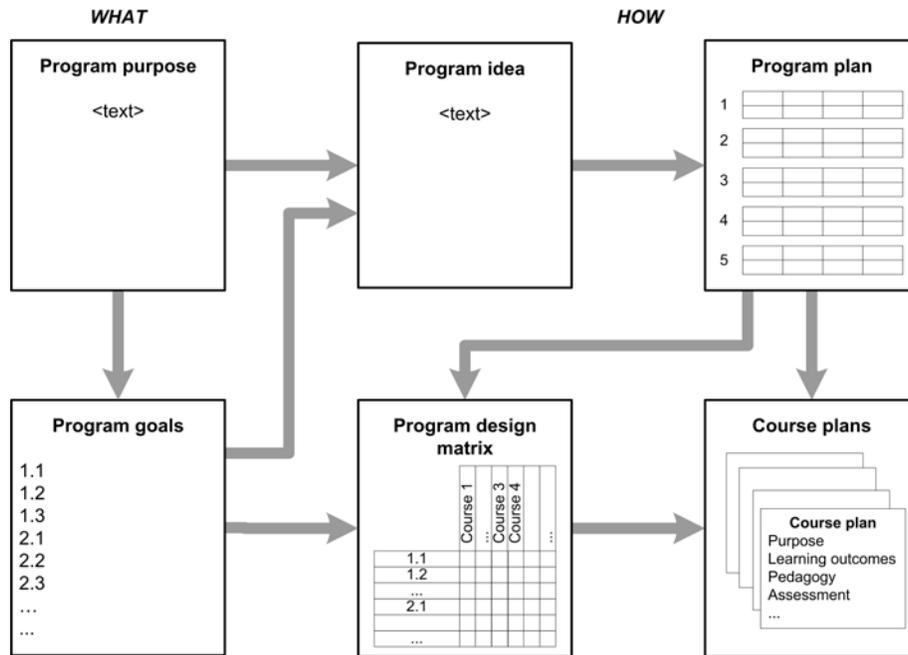


Figure 1. Components of the Integrated program description

makes several passes through the components. In particular, the assignment of goals for learning of generic skills needs to be done in a combined top-down and bottom-up, dialogue-rich fashion between the program chair and the involved faculty, in order to achieve commitment and to transfer ownership for such goals.

Programme Description for the Master's Programme in Product Development

The process for developing the programme descriptions was mainly done by an appointed coordinator for each programme (one of the author). The programme coordinator has an active role in balancing goals and objectives with resources and communicating and establishing decisions on the curriculum. Before moving into reflections on this process a summary of the actual content of the programme description is provided.

Programme Purpose

Given the increased globalization and the competition it leads to, product development has become a core industrial process. Developing products is a multi-disciplinary process of identifying and envisaging user needs and bringing those needs into life. This has to be done in a cost-efficient manner, while ensuring products that exceed expectations on quality standards in form, fit, and function – and stand out from competition.

Product development organizations are thus faced with significant challenges when trying to offer customers better and cheaper products [7]. This includes the harmonization that has to be done between conflicting aspects; the dynamics of the context, making decision-making in constant change a formidable task; the detail of the decision-making that is needed; and that this has to be done under such great time pressure. These decisions have to be taken on technical as

well as business related aspects, an equally important task. These are core aspects in the curriculum for the master's programme in Product Development.

Considering the multi-disciplinary nature of Product Development the master's programme in Product Development is aimed towards students, with a bachelor degree in Mechanical Engineering, Automation and Mechatronics Engineering, Industrial Economics and Management, Industrial Design Engineering, or with an equivalent degree, that want to take part in developing the next generation of outstanding product offers for companies, acting on a global market. The programme is intended to educate students towards professions in product planning, product development, project management, and business development, but also towards research studies.

The Master's programme in Product Development aims to provide an environment and course syllabus that gives students the possibility to attain knowledge, skills and attitudes to efficiently act within global product developing organizations. This includes specific technical knowledge related to product development, managerial skills to plan and control the process, and practical attainments in using advanced methods and tools for collaborative product development. The focal point during the master's programme will be how to operatively develop innovative product offers.

Program Goals

The master's programme in Product Development will give students the possibility to attain competencies in technical as well as managerial aspects of product development. After completed the programme students will be confident in:

1. Conceiving and designing technical solutions that exceed customers and stakeholders expectations.
2. Explaining and assessing product developing companies' organizations and processes.
3. Establish personal and interpersonal skills with the aim to serve within product developing organizations.

In addition, students should have the possibility to pursue deeper studies in order to become confident in the process to:

4. Critically and systematically model, simulate and evaluate mechanical and mechatronic problems with limited or incomplete information.
5. Analyze and understand why and how organizations balance the need for product development with internal resources, and external market and economic forces.

These high-level learning outcomes has been further detailed (see Figure 2) in order to accommodate all different aspects on Product Development and guarantee a good input for further curriculum work.

Programme Idea

The master's programme main idea is to provide students with an education stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating real-world systems and products, in line with the CDIO initiative

1. *Conceiving* and *designing* technical solutions that exceed customers and stakeholders expectations, by being able to:
 - 1.1. *Elicit* and *interpret* customers and stakeholders demands and needs.
 - 1.2. *Harmonise* conflicting interests and information.
 - 1.3. *Establish* a problem definition with technical prerequisites and requirements.
 - 1.4. *Employ* methods for synthesis to *conceive* and *document* solution principles.
 - 1.5. *Make use of, adopt* and *combine* existing mechatronic systems.
 - 1.6. Based on a problem definition and results from performed analyses *choose* and *justify* technical solutions.
 - 1.7. *Demonstrate* and *practice* how to realise technical solutions into refined products to *assure* their quality and robustness.
 - 1.8. *Utilise* advanced tools for computer aided design to *model, analyse* and *optimise* technical solutions.
 - 1.9. *Describe* and *take advantage of* the characteristics of mechatronic systems during product development.
 - 1.10. *Describe* and *take advantage of* the characteristics of advanced design materials during product dev.
 - 1.11. *Demonstrate* and *practice* how to prepare and organise required documentation.
 2. *Explaining* and *assessing* product developing companies' organisations and processes, by being able to:
 - 2.1. *Explain, evaluate* and *implement* different product development strategies, such as platform-based design, modularisation, and standardisation.
 - 2.2. *Describe, Map out, interpret* and *assess* an organisation and its processes.
 - 2.3. *Describe* and *reflect* upon how product development coincide with business development
 - 2.4. *Describe, modify* and *use* advanced IT-tools to manage large sets of product descriptions.
 3. *Establish* personal and interpersonal skills with the aim to serve within product developing organisations, by being able to:
 - 3.1. *Describe* and *utilise* methods for project planning.
 - 3.2. *Describe* and *decide* on applicable means for communication and *practice* these in a development setting.
 - 3.3. *Adopt* a holistic perspective, in which technical progress interacts with human and social progress.
 - 3.4. Be able to *prepare for, control* and *contribute* to multi-disciplinary team work.
 - 3.5. Independently *seek* and *acquire* new info. in order to advance personal knowledge within the area.
- In addition, students should have the possibility to pursue deeper studies in order to become confident in the process to:
4. Critically and systematically *model, simulate* and *evaluate* mechanical and mechatronic problems with limited or incomplete information.
 5. *Analyse* and *understand* why and how organisations balance the need for product development with internal resources, and external market and economic forces.

Figure 2. Learning outcomes for the Product Development Master's Programme following the CDIO principles and syllabus.

(<http://www.cdio.org>), in which Chalmers takes part in. This involves a high degree of group learning experiences, cooperation with industry, and a mix between theoretical and practical elements. The programme will include lectures on state-of the art topics in Product development, self-studies on selected topics, as well as individual and group assignments. A number of assessment techniques will be adopted in the curriculum, including written and oral examinations, project reports, oral presentations, reflection reports, and group diaries. The master's programme will include five parts (see Figure 3): (1) core courses in Product Development; (2) a Multi-disciplinary Product Development Project; (3) Specialization tracks; (4) Elective courses; and (5) a Master's Thesis Project.

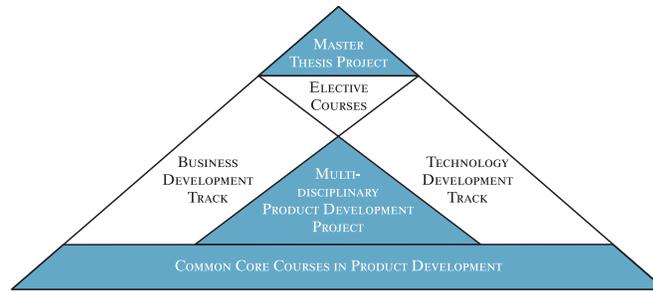


Figure 3. Master's Programme Idea

Programme Plan

The core courses in product development will give a foundation in Product Development aspects, including:

- **Integrated Product Development:** in which key prerequisites for an effective and efficient industrial product development activity will be highlighted.
- **Advanced Computer Aided Design:** in which advanced techniques for computer aided modeling/visualization and geometry assurance will be taught and practiced.
- **Product Planning and Market Analysis:** in which methods and tools for analyzing and understanding different markets and customer needs will be highlighted and used.
- **Product Life Cycle Management:** in which methods and tools for analyzing organizations and processes will be taught and practiced, in order to design an Efficient Digital Development Process.

The multi-disciplinary product development project will be a central part of the first year's curriculum, in which student groups will plan and carry out all phases in a product development project to solve an industrial problem in close collaboration with their industry partners. Projects range from automotive interiors, truck applications to medical devices. The result in the multi-disciplinary product development project is often in the form of sketches, digital models and physical prototypes (see Figure 4). Students enrolled in this course come from the master's programme, but also from other programmes. In relation to the project work, there will be group activities, seminars and individual work supporting the progress in the development projects and the learning process of cooperating in a multi-disciplinary and multi-cultural project group. Following the multi-disciplinary ambition of the master's programme, two specialization tracks will be offered in parallel with this project work:

- The Technology Development Track will include courses in Finite Element Simulation in Design, Applied Mechatronics and Advanced Design Materials.
- The Business Development Track will include courses in Industrial Marketing, Intellectual Property Strategies and Project Management.

Elective courses, given in relation to the master's programme, include Engineering Design, Industrial Design, and Research Methodology. Courses can also be chosen from other suitable programs at Chalmers. Students can also study abroad – collaborations with Universities are being set up.

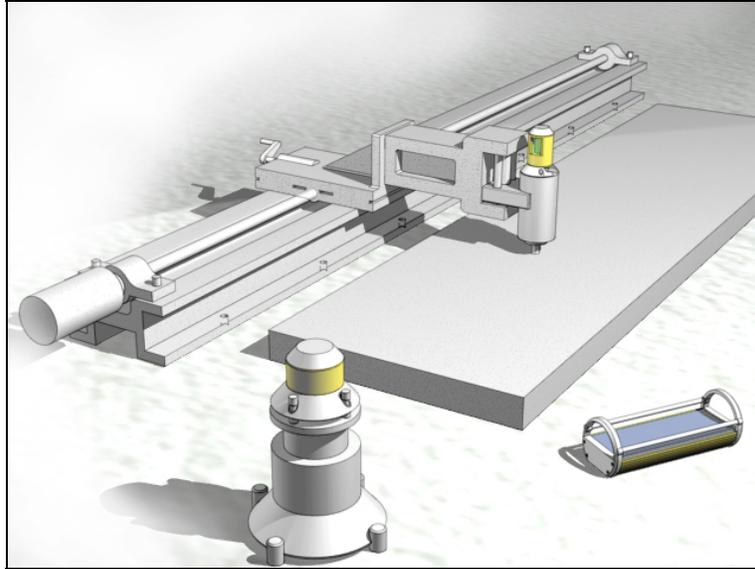


Figure 4. Result from the multi-disciplinary product development project performed by students at Chalmers.

The Master's thesis project will typically be performed at a product developing company in the west of Sweden, or within research projects at the Department of Product and Production Development. Suitable topics range from market and customer analysis, benchmarking, developing new or enhancing existing products or services, to developing new methods, tools or work procedures for product developing organizations. Typically, a master thesis project will be 30 ECTS, However, in more research related topics longer project will be accepted.

Programme Design Matrix

To connect the goals and learning outcomes of the program with its courses, making it is clear in which course each learning outcome is addressed a programme design matrix was developed (see Figure 5).

Experiences on Curriculum Design

Faced with the privileged challenge to design a curriculum for a new Masters' Programme in Product Development one are naturally confronted with some vital questions:

- What skills are product development organisations finding necessary?
- What are the knowledge and engineering experience of the student intake?
- What learning outcomes should the faculty seek to attain?
- What educational elements are likely to attain these outcomes and how should they be organised effectively?
- How can we determine whether these learning outcomes are being attained?

The process to develop integrated process descriptions is an effective support for developing and structuring a curriculum and answering these questions – although the actual process is both top-down, bottom-up, and middle-out.

		ECTS		Compulsory Master Courses					Technology Development			Business Development			Master Thesis Project					
		7.5	7.5	7.5	15	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	30				
1	Conceiving and designing technical solutions that exceed customers and stakeholder's expectations, by being able to:	1.1. Elicit and interpret customers and stakeholders demands and needs.																		
		1.2. Harmonise conflicting interests and information.																		
		1.3. Establish a problem definition with technical prerequisites and requirements.																		
		1.4. Employ methods for synthesis to conceive and document solution principles.																		
		1.5. Make use of, adopt and combine existing technologies.																		
		1.7. Based on a problem definition and results from performed analyses choose and justify technical solutions.																		
		1.8. Demonstrate and practice how to realise technical solutions into refined products to assure their quality and robustness.																		
		1.9. Utilise advanced tools for computer aided design to model, analyse and optimise technical solutions.																		
		1.10. Describe and take advantage of the characteristics of mechatronic systems during product development.																		
		1.11. Describe and take advantage of the characteristics of advanced design materials during product dev.																		
		1.12. Demonstrate and practice how to prepare and organise required documentation.																		
		2	Explaining and assessing product developing companies' organisations and processes, by being able to:	2.1. Explain, evaluate and implement different product development strategies, such as platform-based design, modularisation, and standardisation.																
2.3. Describe, Map out, interpret, and assess an organisation and its processes.																				
2.4. Describe and reflect upon how product development coincide with business development																				
2.5. Describe, modify and use advanced IT-tools to manage large sets of product descriptions.																				
3.1. Describe and utilise methods for project planning.																				
3	Establish personal and interpersonal skills with the aim to serve within product developing organisations.	3.2. Describe and decide on applicable means for communication and practice these in a development setting.																		
		3.3. Adopt a holistic perspective, in which technical progress interacts with human and social progress.																		
		3.4. Be able to prepare for, control and contribute to multi-disciplinary team work.																		
4	Critically and systematically model, simulate, and evaluate mechatronic problems with limited or incomplete information.																			
5	Analyse and understand why and how organisations balance the need for product development with internal resources, and external market and economic forces.																			

Figure 5. Programme Design Matrix for the Master's programme (I-Introduce, T-Teach, U-Use)

What skills are product development organisations finding necessary?

Core aspects in the curriculum for the master's programme in Product Development are influenced by the fact that, when developing successful products, costs and time constraints and business objectives matter (not just functionality and performance) and that the development depends on teamwork by creative people. However, a primary objective with the curriculum is to enable students to transfer their engineering and science understanding in a design context. Consequently, the aim of the programme is two folded, first to make the development process as effective as possible, and secondly to develop as superior products as possible.

What are the knowledge and engineering experience of the student intake?

Considering that all lectures will be held in English and the ambition is to attract foreign students this is not an easy task. Since the programme is primarily designed to fit undergraduate students from Chalmers our work has been to ensure that introductory courses have a purposeful entrance level on relevant subjects. We require that our students in addition to knowledge in basic science and engineering also have knowledge in areas such as industrial organisations and economics and basic design methodology. But considering the wide-spread use of corner-stone projects in undergraduate curriculum and the infusion of first-year design courses [8], this has been assessed not to be a major problem.

What learning outcomes should the faculty seek to attain?

Writing learning outcomes has been a good way in communicating curriculum ideas with colleagues in an abstract way. As a researcher in Requirements Engineering this comes rather natural – stating what functionality and performance that is needed by the intended system (i.e. the students), rather than specifying technical solutions (i.e. educational elements). Since, the importance of being clear about the purpose of the curriculum is well accepted this has not been controversial.

A concern of writing learning outcomes in this structured fashion is that it might restrict the curriculum to a narrow range of student skills and knowledge that can be readily expressed – but what about those that cannot be simply stated? Nevertheless, writing learning outcomes has smoothed the development and communication process and one probably has to accept that not all aspects are explicitly covered. Another concern is whether or not you should write learning outcomes for the “best” projected programme or if you should concurrently balance the learning outcomes with the resources at hand (e.g. competencies within the faculty, possibility to develop new courses, etc.)? The programme design matrix presented in figure 5 is related to the situation when the programme starts this autumn, considering the tight time-schedule and the resources at hand. In our case, the “best” projected description will act as the goal for the curriculum work that will come the next following years, curriculum roadmaps is currently used for planning and aligning curriculum development.

What educational elements are likely to attain these outcomes and how should they be organised effectively?

When developing a curriculum for a whole programme it's always a question on how far into detail you should go. Rather than specifying educational elements we have encouraged course examiners to adopt project or problem based elements that encourage analysis and synthesis leading to a transfer of attained skills and knowledge into a design context. We have also

encouraged a high degree of practical elements in courses coupled with reflection on this action. Much effort has also been put on creating a fruitful learning progression and make sure that all educational elements fits together – primarily in the cross-section in-between courses.

How can we determine whether these learning outcomes are being attained?

From a programme perspective we have not gone into a detailed discussion about how to assess learning outcomes – we have though encouraged and guaranteed that a varied form of purposeful assessment techniques is used within the programme and that each learning outcome in individual courses will somehow be connected to an active assessment.

Experiences on Using the CDIO standards and syllabus

Using the CDIO standards and syllabus and the process for developing integrated program descriptions has certainly provided for systematic planning and documentation of the curriculum design. In this sense it has given a foundation for communication and decision-making. This has made it possible to decide on what measures to take and develop action plans – all this based on the professional role of an engineer, not only on the domain knowledge of a certain discipline. However, the mayor benefit lies in the holistic perspective it gives on curriculum design, rather than focusing on specific course elements and the expected inheritance from previous courses etc.

As stated earlier, a concern of writing learning outcomes in this structured fashion is that it might restrict the curriculum to a narrow range of student skills and knowledge that can be readily expressed. As expected, it creates a focus on the detailed elements in the syllabus (i.e. Section two, three and four in the CDIO Syllabus: *Personal and Professional Skills and Attributes, Interpersonal Skills: Teamwork and Communication, Conceiving – Designing – Implementing and Operating Systems in the Enterprise and Societal Context*) and special attention needs to be addressed to specific disciplinary domain knowledge. In addition, specific learning outcomes has not been written addressing proficiency levels, this has rather been addressed within course descriptions.

Conclusions

Given that Chalmers has provided a general process to describe all master's programmes in a structured fashion has not only made it possible to develop a specific programme but also made it possible to areas for synergies between related programmes. As a coordinator for a programme this process and the described methods and documents has made it possible to develop and communicate educational elements in an abstract fashion without proposing specific in-class activities. Since, the focal point of these describes procedure are on specifying learning outcomes and educational elements and packaging these into appealing courses for a programme it do not support the process to develop a masters' programme that involves something more than just its courses – a work that has been done in parallel.

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